

Lunar Orbit Mission Risk Analysis using the Integrated Medical Model



Aerospace Medical Association

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Eric Kerstman, MD, MPH

Aerospace Medicine Physician/Flight Surgeon

Clinical Lead – Integrated Medical Model

Advanced Technologies for Engineering and Medicine

Wyle Integrated Science and Engineering

ekerstman@wylehou.com

(281) 212-1305

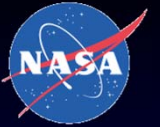
Millennia Foy, PhD

Lead Modeler – Integrated Medical Model

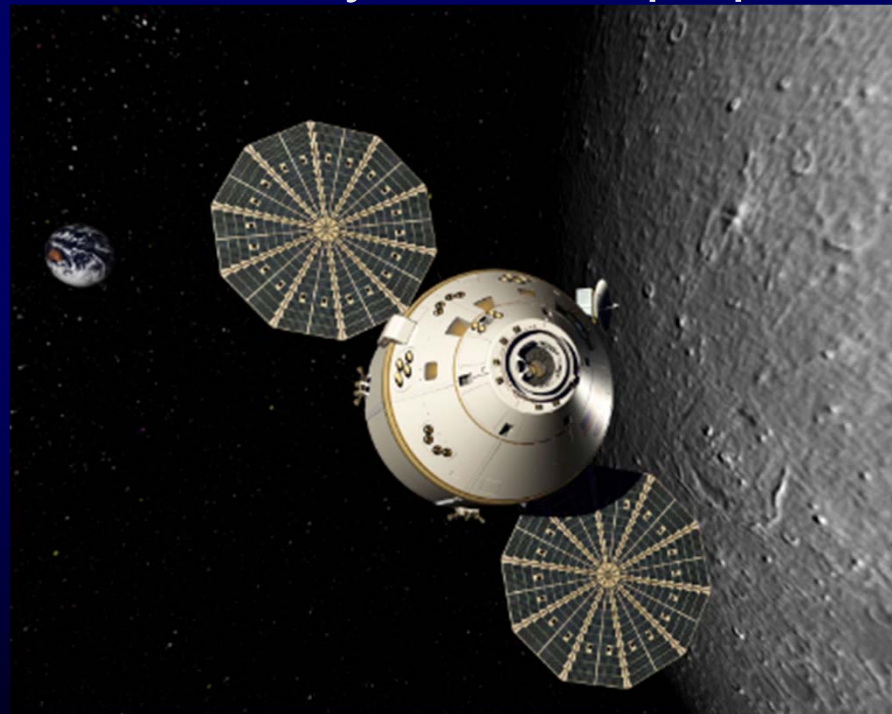
Advanced Technologies for Engineering and Medicine

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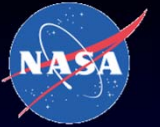
Orion Multipurpose Crew Vehicle



- Carries the crew to orbit and exploration destinations
- Sustains the crew while in space
- Provides safe re-entry from deep space



Exploration Flight Test-1 (EFT-1)



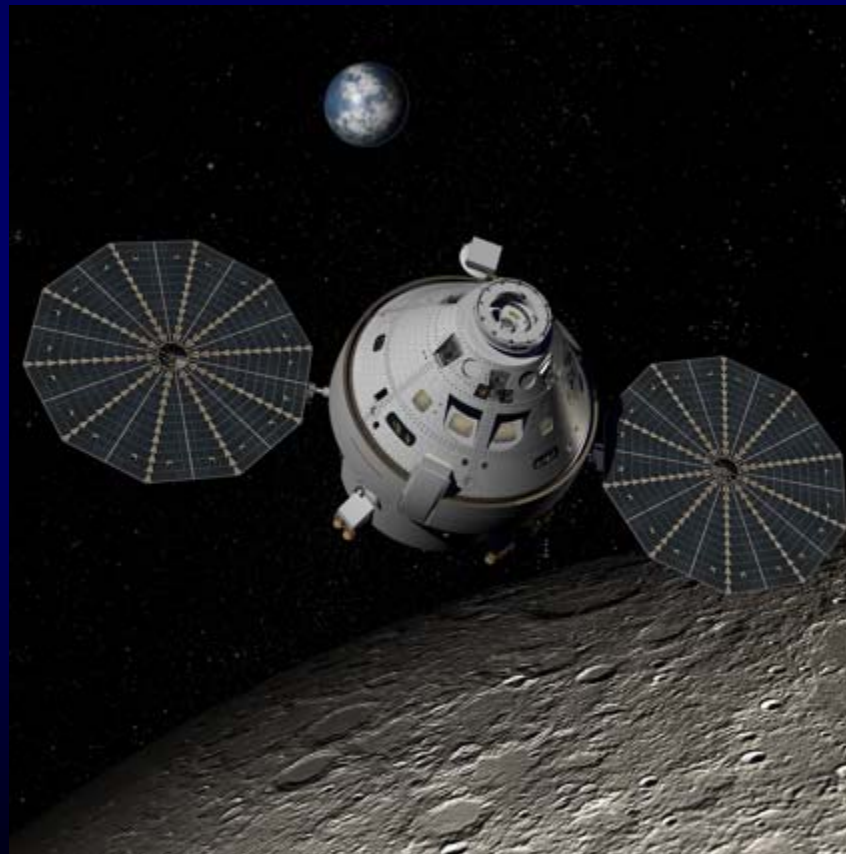
- Scheduled for September of 2014
- High earth orbit of 3600 miles
- Re-entry speed of 20,000 mph



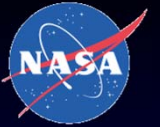
Exploration Mission-1 (EM-1)



- An un-crewed mission beyond earth orbit (lunar flyby)
- Planned for 2017



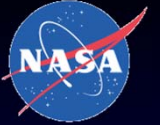
Exploration Mission-2 (EM-2)



- A crewed mission beyond earth orbit (lunar orbit)
- Planned for 2021
- Mission duration of 10 to 14 days
- Mission Objectives
 - Demonstrate safe crewed flight beyond low earth orbit
 - Validate the life support system
 - Validate crew operations



EM-2 Design Reference Missions

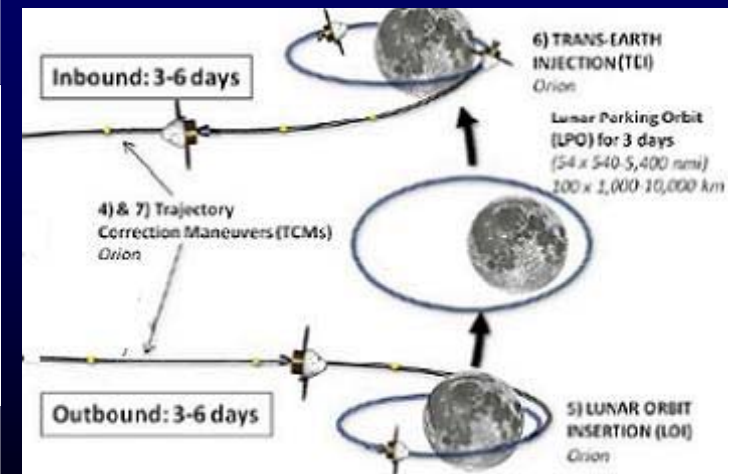
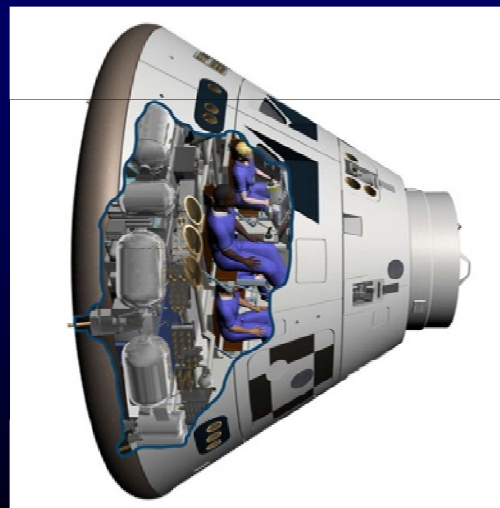
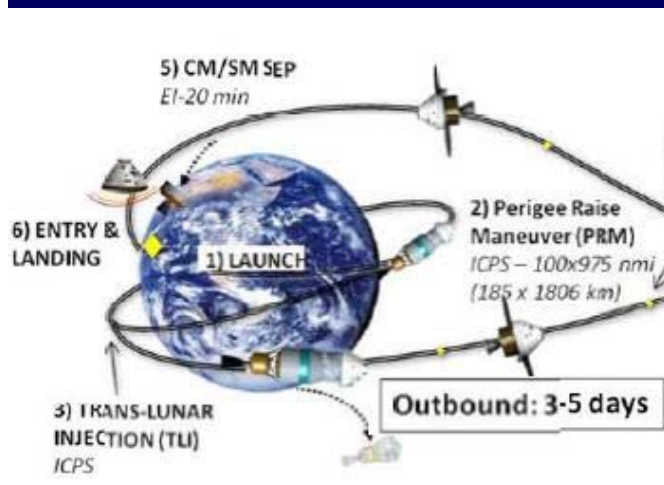


- EM-2 Crewed Lunar Orbit (CLO)
 - 14 days
 - 4 crew members
 - No extravehicular activity
- EM-2 Distant Retrograde Orbit (DRO)
 - 25 days
 - 2 crew members
 - No extravehicular activity
- EM-2 Hybrid
 - 12 days
 - 2 crew members
 - No extravehicular activity

EM-2 Medical Risk Analysis



- What is the probability of loss of crew life (death) due to a medical event during a lunar orbit mission?



Integrated Medical Model (IMM)



- IMM Background
 - Software model used to simulate manned space flight missions
 - Simulates medical events during space flight missions
 - Estimates the impact of these medical events on crew health and mission success
 - Outputs include estimates of crew health, probability of medical evacuation, and probability of medical loss of crew life
 - Optimization routines can be used to design medical systems which maximize crew health and probability of mission success

Life Before IMM

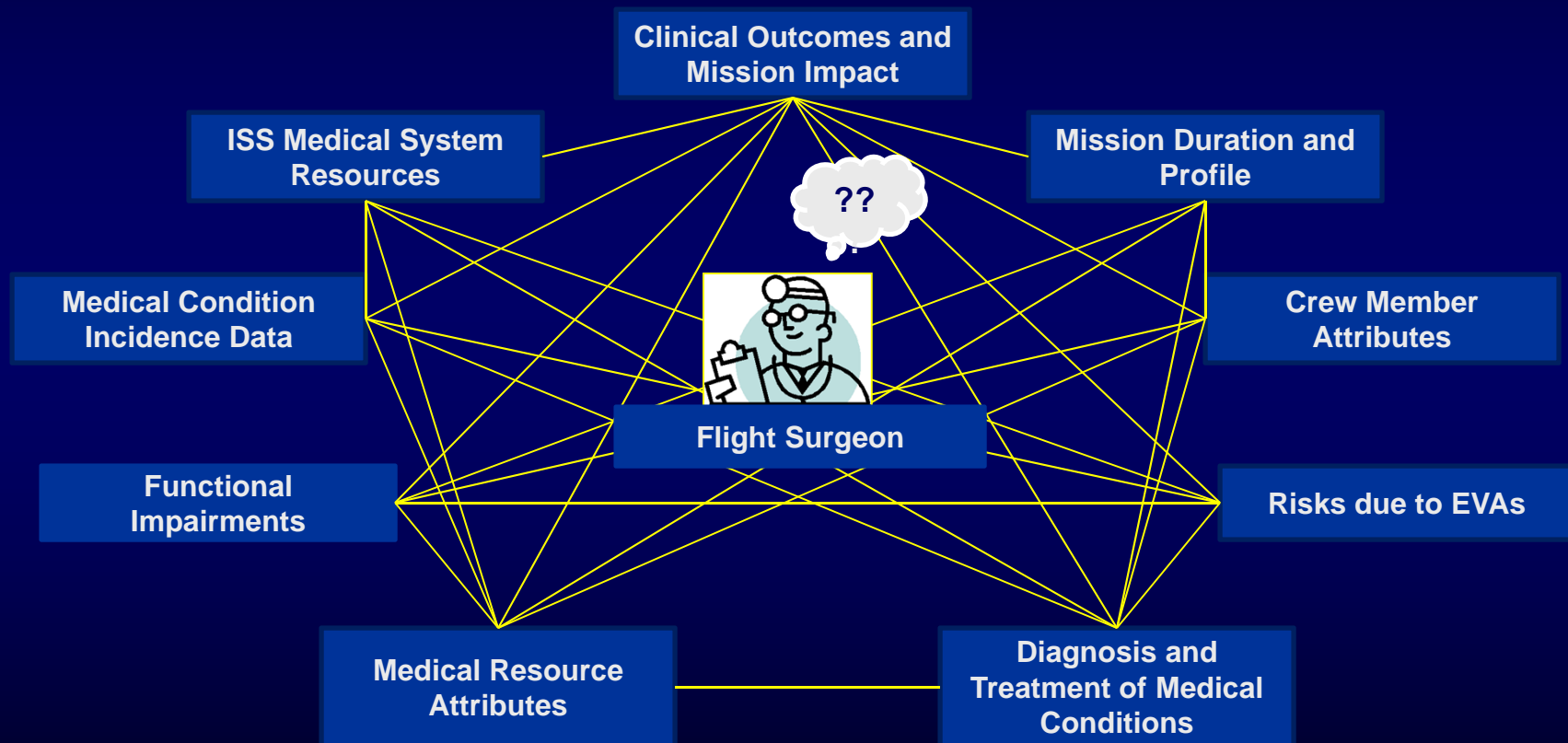


What is the likelihood of a medical evacuation?

What is the risk of Loss of Crew Life due to illness on ISS?

What medical devices should we have on ISS?

What should be in the Exploration Medical Kit?

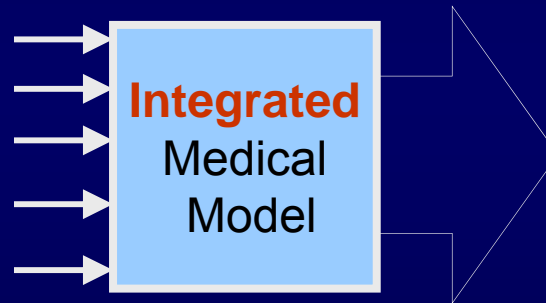


IMM Conceptual Model



Inputs

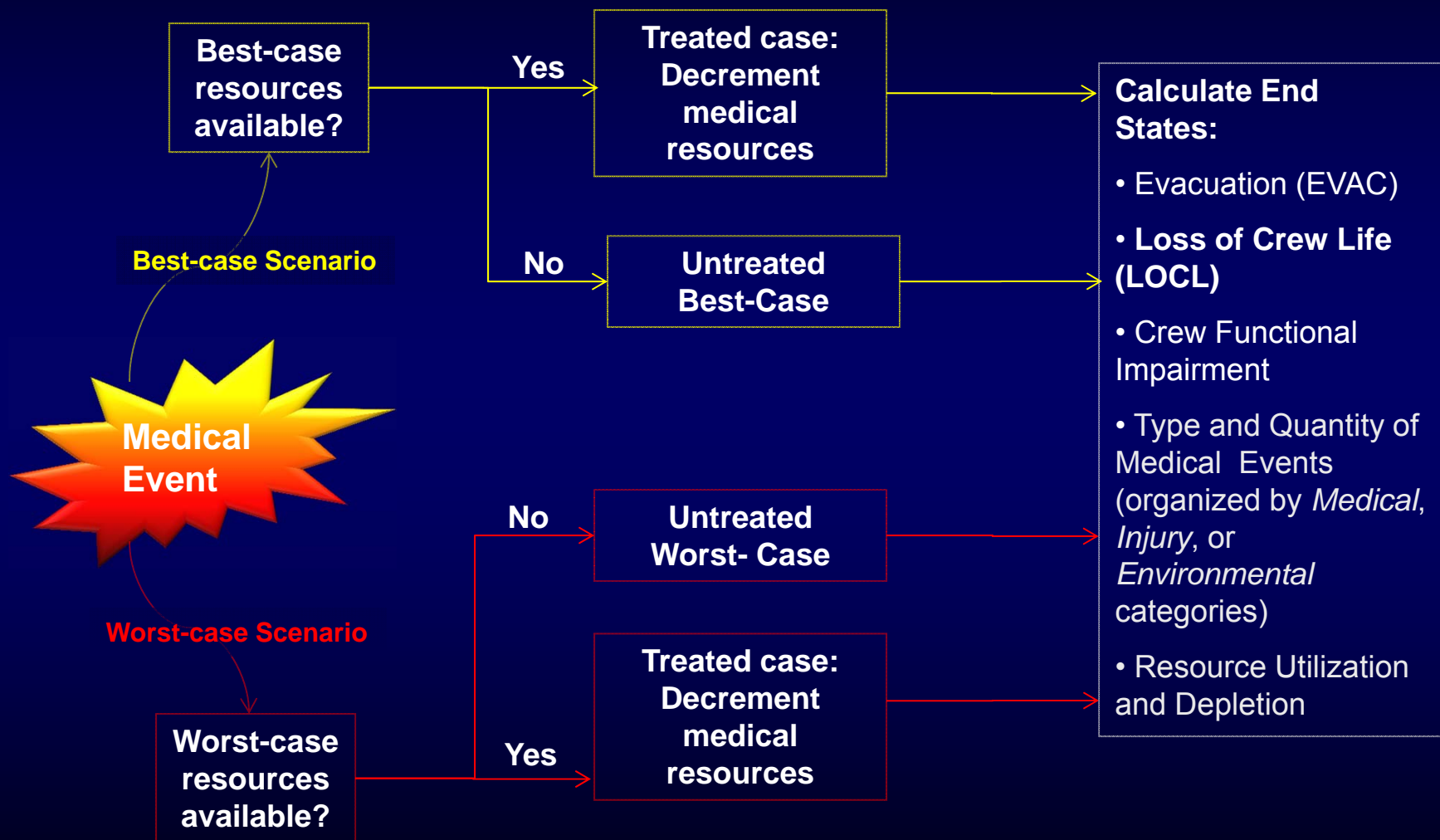
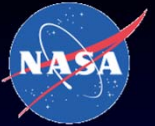
- Medical Conditions & Incidence Data
- Crew Profile
- Mission Profile & Constraints
- Potential Crew Impairments
- Potential Mission End states
- In-flight Medical Resources



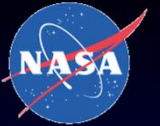
Outputs

- Medical Condition Occurrences
- Crew Impairments
- Clinical End States
- Mission End States
- Resource Utilization
- Optimized Medical System

IMM Logic - Event Sequence Diagram



Life Now with IMM



Mission Specific Inputs

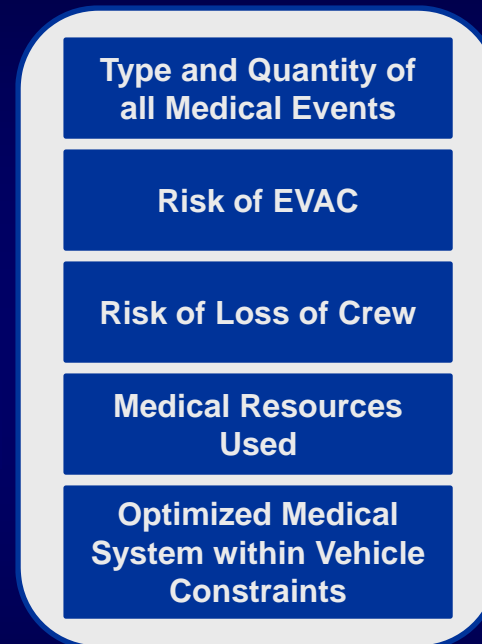


Monte Carlo Simulations



13,500+ data elements

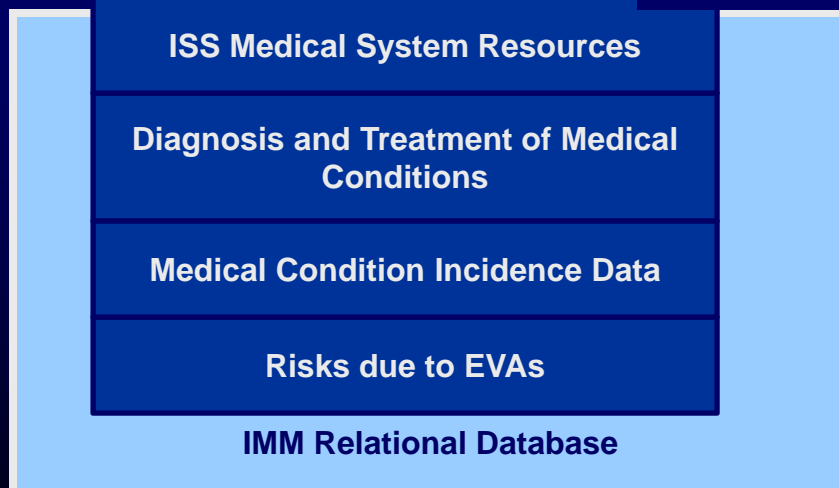
Quantified Outputs



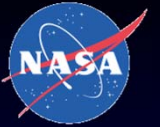
Informed Analysis



Flight Surgeon



Methods



- What is the probability of loss of crew life (death) due to a medical event during a lunar orbit mission?
- IMM Analysis of EM-2 CLO
 - Define DRM (4 crew, 14 days, no extravehicular activity)
 - Define medical system constraints (13.6 kg, 6144 cm³)
 - Simulate 100K missions using Monte Carlo methodology
 - Use the IMM optimization routine to minimize the probability of LOCL within the above medical system constraints



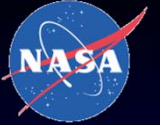
Results



- *Optimized medical kit had a mass of 4 kg and a volume of 6144 cm³
- **Probability of LOCL = 0.1% (1 in 1000 missions)**
with 95% confidence interval of 0.08% to 0.11%
- Probability of EVAC = 2.45%
- Crew Health Index = 87.52%

*No allowance for packing factor (typically 20% to 30%)

Summary and Conclusions



- A crewed mission beyond earth orbit (lunar orbit) is planned for 2021
- DRM EM-2 Crewed Lunar Orbit (CLO) is a 14 day mission with 4 crew members and no scheduled EVAs
- Based on IMM analysis, the probability of LOCL due to a medical event is estimated as 0.1%
- The optimized medical kit reached volume constraints prior to mass constraints
- IMM can be used to estimate crew health, and probabilities of LOCL, EVAC for exploration missions
- IMM can be used to help optimize medical kits for exploration missions with mass and volume constraints

Questions and Discussion



ekerstman@wylehou.com

Back-up Slides



Medical Kit Contents



<u>Medications</u>	<u>Quantity</u>	<u>Equipment</u>	<u>Quantity</u>
Afrin	1	ACE Bandage	1
Amoxicillin	30	Blood Pressure Cuff	1
Aspirin	24	Camera	1
Azithromycin	6	Dental Mirror	1
Bacitracin	1	Finger Splint	1
Bactrim	20	Fluorescein Strips	3
Bactroban	1	IV Administration Set	1
Imodium	16	Otoscope	1
Levaquin	2	Ophthalmoscope	1
Motrin	40	Medical Oxygen	1
Pepto-Bismol	12	Pulse Oximeter	1
Prilosec	7	SAM Splint	1
Rocephin	1	Silver Nitrate Stick	1
Sudafed	29	Tourniquet	1
Tobradex Eye Drops	1	Urine Chemstrips	2
Tylenol	50	Urinary Catheter	1
Vicodin HP	30		
Zithromax	6		



Medical Conditions in IMM by Category

Injury/Trauma

Acute Compartment Syndrome
Abdominal Injury
Back Injury
Chest Injury/Pneumothorax
Dental Tooth Avulsion
Eye Abrasion
Eye Penetration
Elbow Dislocation
Finger Dislocation
Fingernail Delamination (EVA)
Head Injury (TBI)
Hip/Proximal Femur Fracture
Hypovolemic Shock
Lower Extremity Stress Fracture
Lumbar Spine Fracture
Neck Injury
Neurogenic Shock
Paresthesias/Hot Spots (EVA)
Shoulder Dislocation

Environmental

Acute Radiation Sickness
Altitude Sickness
Barotrauma (ear/sinus block)
Burns
Decompression Sickness (EVA)
Eye Chemical Burn
Headache (CO₂ induced)
Smoke Inhalation
Toxic Exposure

Medical Conditions by Category



Medical Illness

Abnormal Uterine Bleeding

Acute Arthritis

Acute Prostatitis

Allergic Reaction

Anaphylaxis

Angina

Anxiety

Appendicitis

Afib/Aflutter

Back Pain (SAS)

Behavioral Emergency

Biliary Colic

Cardiogenic Shock

Choking

Constipation (SAS)

Dental Abscess

Dental Avulsion

Dental Caries

Urinary Tract Infection

Urinary Retention

Dental Crown Replacement

Dental Exposed Pulp

Dental Filling Replacement

Depression

Diarrhea

Eye Corneal Ulcer

Eye Infection

Gastroenteritis

Acute Glaucoma

Headache (late)

Headache (SAS)

Hemorrhoids

Hypertension

Indigestion

Influenza

Insomnia (SAS)

Insomnia (late)

Kidney Stone

Vaginal Yeast Infection

Visual Impairment (VIIP)

Medication Overdose

Mouth Ulcer

Nasal Congestion (SAS)

Nosebleed (SAS)

Otitis Externa

Otitis Media

Pharyngitis

Respiratory Infection

Shingles

Seizures

Sepsis

Sinusitis

Skin Infection

Skin Rash

SMS (SAS)

Stroke

Sudden Cardiac Arrest

Urinary Incontinence

Urinary Retention

SAS = Space Adaptation Syndrome

IMM Team



- Douglas Butler, MBA – Project Manager
- Eric Kerstman, MD, MPH – Clinical Lead
- Millennia Foy, PhD – Lead Modeler/Epidemiologist
- Marlei Walton, PhD – Project Scientist
- Lynn Saile, RN, MS - Clinical Informatics Lead
- Lynn Boley, RN, MSN - Clinical Researcher
- Ronak Shah, DO, MPH – Medical Reviewer
- Alexander Keenan, MS - Modeler
- Jerry Myers, PhD – External Module Lead